Effect of iron slag as partial replacement of fine aggregates on the characteristics of self-compacting concrete

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ABSTRACT

The iron and steel industries the main source of the production of iron slag. This paper presents the results on an experimental program carried to preformed the possibility of use of iron slag as partial replacement of fine aggregate (sand) in self-compacting concrete (SCC).. Modern application of self-compacting concrete (SCC) is focused on high performance. Mix were designed for M-50 grade and fine aggregates were replaced with 0, 5,10,15,20,25,30,35,40,45, and 50% iron slag. Tests were performed to evaluate the fresh properties, strength properties and Flexural strength analysis of SCC. Fresh Properties such as slump flow, V-funnel, U-box, L-box, Strength properties such as compressive strength, splitting tensile strength, and flexural strength were examined. Results indicated that compressive strength, splitting tensile strength and flexural strength of self-compacting concrete improved with increase up to some percentage of iron slag at all the curing ages.

Keywords: Iron Slag, River Sand, Compressive strength, Flexural strength, Super plasticizer.

I. INTRODUCTION

Concrete is compacted by vibrations in order to expel entrapped air and homogeneous because compaction is necessary to produce durable concrete. Recognizing the lack of uniformity and the complete compaction of concrete by vibration, investigates at the college of Tokyo, Japan begun in late 1980"s to created SCC. By the early 1990"s Japan has created the concrete which does not required vibration to realize full compaction. By the year 2000, the SCC ended up well known in Japan for prepared blend concrete. Several European countries show the significance and potential of SCC developed in Japan. During 1989, Self-compacting concrete (SCC) can be characterized as a concrete which can be put with its own weight or without vibration. It encourages and guarantees appropriate filling and great basic execution of intensely fortified congested members.

Natural sand (fine Aggregate) is getting exhausted due to expanded utilization of concrete. As a result, substitutes of common sand are being investigated by utilizing squander materials and mechanical byproducts. Quality and strength properties are essentially influenced by type of fine Aggregate. The first generation of SCC used in North American was characterized by the use of relatively high content of binder as well as high dosages of chemicals admixtures, usually super plasticizer to enhance flow ability

Stability. Various industrial by products, are used successfully in the manufacturing of durable SCC such as fly ash, silica fume and ground granulated blast furnace slag, steel slag and copper slag etc. to reduce the use of Natural sand (fine aggregates). One such byproduct is iron slag (IS). In several research iron slag, by product of metal extracting material found to be used as replacement of sand in concrete.

Large volume of iron slag disposed out in open land or in Natural resources in near-by areas which pose great harm to living beings and Natural resources. Use of iron slag in the manufacturing of concrete is the good overture to its disposal. With continuous increase in the production of iron slag, it is necessary to use it in concrete rather than disposalin open land. Several researchers have focused on iron slag as supplementary material in place of sand in concrete. In SCC replacement of iron slag as sand replacement gives reassuring findings of strength properties. Despite of these results, a very less literature are being performed on SCC incorporating iron slag as fine aggregates has been communicated. Particle size ranges from fine sand. The appearance and particle size distribution of iron slag are more over similar to river sand. The principal constituents of iron slag are silica (SiO2), alumina (Al2O3), calcium (CaO), and magnesia (MgO), which make up 95%. The rough vesicular texture of slag provides larger surface area in comparison to smoother aggregates which provides good bond with ordinary Portland cement. Literature survey indicates that there is no published work related to use of iron slag in self-compacting concrete. Literature review was concentrated on use of iron slag in concrete as well as self-compacting concrete. Explored on good quality concrete arranged from copper slag as fine totals at 40% and nano-silica up to 2% substitution. Comes about appear that exceptionally moo fast chloride penetrability values at 28 and 90 days. Water retention values decrease with increase in copper slag substance. Deboucha accepted that impact heater slag progresses the quality and toughness properties of concrete blends. Luster et al. Explored the impact of utilizing oxidizing and lessening slag gotten from stainless steel making as sand on the building concrete properties. Inquire about concluded all designing properties were comparable with control blend and it might spare taken a toll up to 43% with 100% substitution of stainless steel oxidizing slag as coarse totals and 30% portion of stainless steel diminishing slag substitutes to Portland cement in SCC. Afshoon and Sharifi inspected the results of ground copper slag as substitutes of cement on new properties of SCC. Seven blends made with settle water powder rastio. Conducted tests to discover out resistance of alkali-activated slag (AAS) concrete to sulfate assault. These tests incorporates drenching in 5% MgSo4 and 5% Na2So4 arrangements and watched that the quality decrease was up to 17% for alkali activated slag (AAS) concrete and up to 25% for conventional Portland cement (OPC) concrete after 12 months presentation to sodium sulfate for OPC after increasing the slag content the slump values gradually decreases, V-funnel time and box fillings was almost achieved.

The purpose of this investigation was to find the compressive strength, and durability properties such as rapid chloride permeability, water absorption, sulphate resistance and ultra-sonic pulse velocity of self-compacting concrete made from iron slag.

II. EXPERIMENTAL

2.1 Materials

2.1.1 Cement

Portland cement was used in this work, which conformed to BIS: 8112-1989

2.1.2 Fine aggregate (river sand)

River sand was used as fine aggregate, and satisfied the requirements for grading zone-II . Its specific gravity and fineness modulus values were 2.45 and 2.62 respectively.

2.1.3 Coarse aggregate

Locally available gravel of 12 mm size was used as coarse aggregate. Its specific gravity was 2.59 and fineness modulus was 6.97.

2.1.4 Iron slag

Iron slag was collected from a local iron and steel rolling mills. It was black in color. The chemical composition of iron slag is given in Table 1. Specific gravity and fineness modulus of iron slag is 2.49 and 2.72 respectively.

Table 1

Chemical composition of iron slag.

Chemical Compound	Formula	%Age of chemical compound
Iron Oxide	Fe_2O_3	66.88
Silicon dioxide (silica)	SiO_2	6.98
Aluminum oxide (alumina)	Al_2O_3	2.94
Calcium oxide (lime)	CaO	0.8
Carbon dioxide	CO_2	22.40

2.1.5 Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable.

2.1.6Admixture

Aura-mix 400 is uncommon combination of the latest generation super-plasticizers, based on a polycarboxylic ether polymer with long lateral chains. It is light yellow colored liquid with 6.0 pH (min.) value.

2.2 Mixture proportions

The mixture proportion of SCC was selected by trial mixes. Control mixture achieved strength of 50 MPa at the age of 28 days.compressive strength at 28 days. Then river sand was replaced with 5,10,15,20, 25, 30,35,40,45 and 50% iron slag. The control SCC mixture was designated as "SCC-CM", and SCC mixtures with 05,10,15,20,25,30,35,40,45 and 50% iron slag were designated as SCC-IS10, SCC-IS25 and SCC-IS40 respectively. All the mixtures also contained 10% of silica fumes weight of cement and 1.2% of super plasticizer was added by weight of cement.

minutes from starting of mixing. It was conclude that the proper addition time of superplasticizer was 1.5–3 min which produced a mixture of high flowability and good consistence.

Table 2

Mixture proportion of SCC with iron slag.

Mixture ID	SCC-CM	05%	10%	15%	20%	25 %	30%	35%	40%	45 %	50%
Cement (kg/m³)	495	495	495	495	495	495	495	495	495	495	495
Silica Fume (kg/m³)	55	55	55	55	55	55	55	55	55	55	55
Sand (kg/m³)	917	871	825	779	733	687	641	596	550	504	458
Iron slag (kg/m³)	0	45	91	137	183	229	275	320	366	412	458
Iron slag (%)	0	05	10	15	20	25	30	35	40	45	50
Coarse aggregates (kg/m³)	787	787	787	787	787	787	787	787	787	787	787
Water (Lit/m³)	165	165	165	165	165	165	165	165	165	165	165
Admixture (%)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.20

The amount of powder content was 450–530 kg/m3 and silica fume replacement ratio ranges from 0% to 20% in the steps of 5% by volume. For all mixes, the sand to mortar volume ratio of 11% and the coarse aggregate to concrete volume ratio of 9.5% were maintained constant. The test of SCCs were carried out with the same fresh concrete properties, a slump flow of 700 ± 50 mm, a v-funnel time of 8.0 ± 3.0 seconds, l-box height H2/H1=0.8-1.0 and segregation index in sieve stability test of less than 15%. To enhance suitable for such structures as walls, columns and slab.

2.3. Mix procedure, casting, curing and testing

2.3.1. Mix procedure for SC

From all materials, superplasticizer is one of the most important materials to produce SCC. A proper procedure of mixing should result in the greatest efficiency in its action. There are two methods of mixing super plasticizer to the mix, first is direct addition and second is delayed addition. In the direct addition, first the water and super plasticizer then the cement were mixed into the mixer which starts to mix followed by adding the fine aggregate. This method result to let cement get in contact with super plasticizer. For the delayed addition, all required materials except the superplasticizer are mixed with each other and the remaining mixing water was added with superplasticizer after several

2.3.2. Tests on fresh SCC

Tests of SCC on fresh properties, include slump flow, vfunnel test, l-box test. The result of this test are given in table 2 and table 3.

Slump Flow:- The maximum flow of concrete in absence of any obstructions was conducted by slump flow test in which the slump cone was filled mixed without any compaction. The value of Slump flow is the average of the two diameters cone in perpendicular directions of the concrete after lifting the cone and until concrete stops flowing.

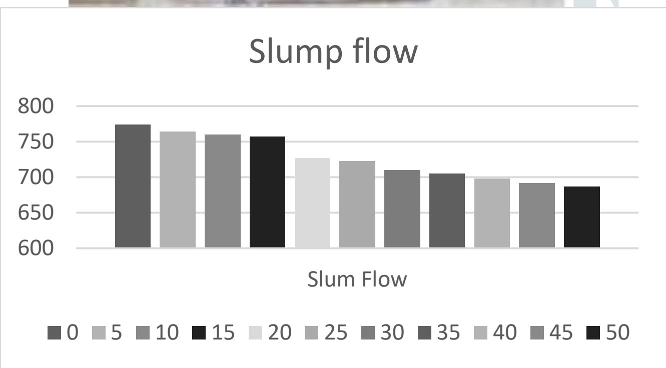

Fig. 1. Effect of iron slag on slump values

V-funnel:- This test is used to determine the filling ability properties (flow ability) of the concrete. The funnel is filled up with 12 liter of concrete. Find the time taken for its flow down. V-funnel value is the time of concrete flowing from the opening at the bottom of the funnel. Both the test gives indications of flow ability of concrete.

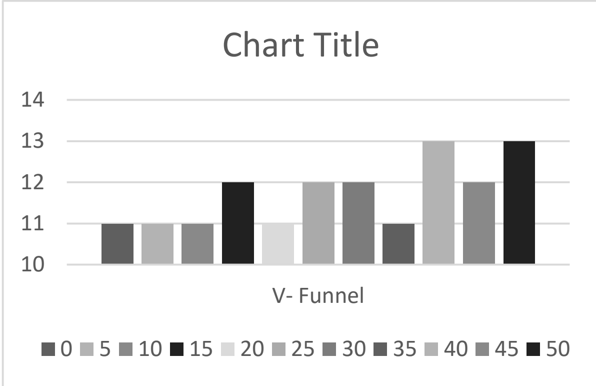

Fig. 2. Effect of iron slag on V –Funnel test

L- Box:- This test assesses the flow of concrete and also the extended to which the concrete is subjected to blocking by reinforcement. About 14 liter of concrete is required for the test and let it rest for 1 minute before the test.

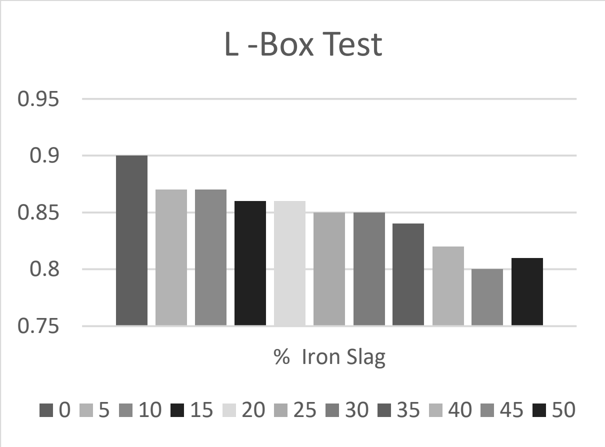

Fig. 3. Effect of iron slag on L-box values.

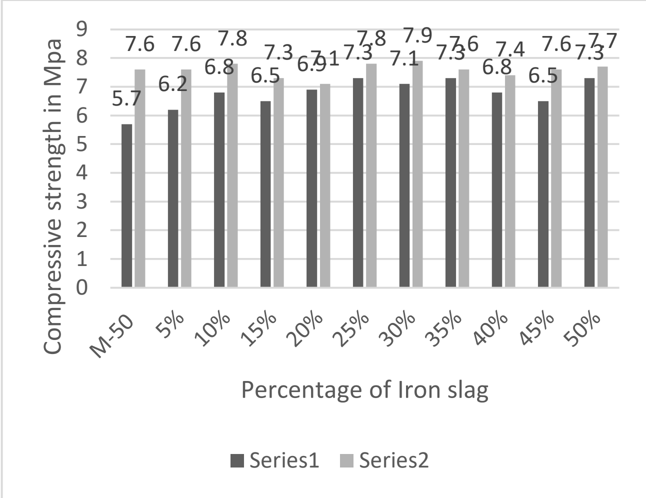

Fig. 4. Effect of iron slag on Compressive Strength

The following results are obtain form the test on fresh properties of SCC are given below.

Table 4: Result of fresh properties with nominal mix.

Mixture ID	Slump flow (mm)	L-box (H2/H1)	V-funnel (sec.)
SCC-CM	774	0.91	11
SCC 05%	764	0.90	11
SCC 10%	760	0.87	11
SCC 15%	757	0.87	12
SCC 20%	727	0.86	11
SCC 25%	723	0.86	12
SCC 30%	710	0.85	12
SCC 35%	705	0.85	11
SCC 40%	698	0.84	13
SCC 45 %	692	0.82	12
SCC 50%	687	0.80	13

III. Strength Properties

3.1 Compressive strength

Fig. 4 shows that replacement of iron slag leads to increase in compressive strength at 7 days and 28 days testing period. The strength increment is not only cause of rigidity of changing aggregates but in fact, it is a good quality of interfacial transition region over the aggregate. Compressive strength of control mixture of SCC without iron slag is 45.7 MPa, 48.5 MPa and 49.3 MPa at 28, days respectively. Compressive strength at 28 days of SCC mixtures made with 10, 25 and 40% iron slag as fine aggregates gained 4, 13 and 21% respectively more compressive strength in comparison with Control SCC (without iron slag).

3.2 Flexural strength test

Flexural strength test results are shown in Fig. 5 show similar increment in flexural strength as in case of compressive strength and splitting tensile strength. At 7 days, SCC mixtures containing 05, 10, 15, 20, 25, 30, 35, 40, 45, and 50% iron slag as fine aggregates obtained 2.5, 12 and 18% more flexural strength as compared with control mix. At 28 days, SCC mixtures containing 10%, 25%, 40% iron slag as fine aggregates obtained 1, 5 and 14% more flexural strength as compared with control mix. more flexural strength as compared with control mixture. Kothei and Malatya presented the results of SCC made with 10 to 100% of steel slag as replacement with fine aggregates. It was concluded that up to 40% replacement of fine aggregates with steel slag gives the better results of flexural strength. These results are comparable with the results of this study and similar finding of flexural strength results was reported by Paid et al.. In this research, flexural strength increases with the increase of iron slag content. It is clear that the flexural tensile strength.

Table 5

Splitting tensile strength and compressive strength ratios.

SCC Mixture	Splitting tensile strength/compressive strength ratio (%)	
	7 days	28 days
SCC-CM	5.7	7.6
SCC -05%	6.2	7.6
SCC-10%	6.8	7.8
SCC-15%	6.5	7.3
SCC- 20%	6.9	7.1
SCC- 25%	7.3	7.8
SCC-30%	7.1	7.9
SCC-35%	7.3	7.6
SCC-40%	6.8	7.4
SCC_45%	6.2	7.6
SCC-50%	7.3	7.7

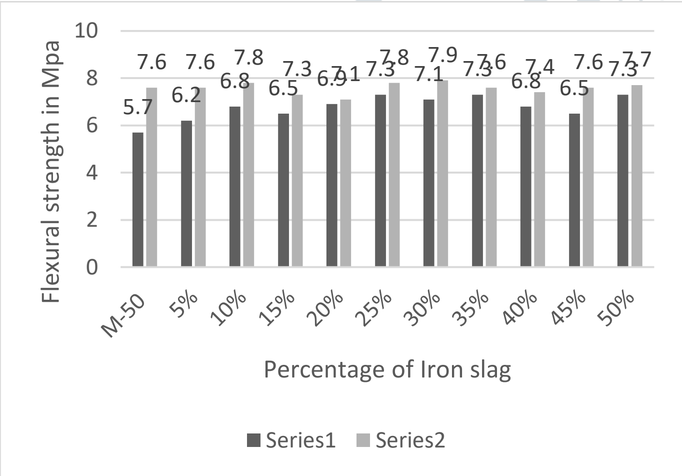

Fig.5. Effect of iron slag on flexural strength.

IV. CONCLUSION

The present experimental study was carried out to investigate the factibility of using iron slag as a replacement of fine aggregates in SCC. Experiments were conducted by replacing fine aggregates with iron slag in varying percentages in SCC. Test result indicates that iron slag is a good candidate to be used in partial replacement of fine aggregates in production of structural self compacting concrete of grade between M50 and M60. Based on the analysis of test results, the following conclusions can be drawn. The results show that slump values, U-box values and L-box values decreased with the increase in level of iron slag. V-funnels test value of time is increased as the iron slag content dose. The rough texture and complicated shape of particles of iron slag, which plays a significant role in increasing the interparticle friction. The above factor contributed lowering the slump, L-box and U-Box and increase passing time in V-funnel values. Therefore, it can be concluded that decrease in workability of SCC on use of iron slag.

Compressive strength, splitting tensile strength and flexural strength increase with increase of iron slag percentage. The maximum increase in compressive strength is 20% at all ages (7, 28 days) with 50% replacement. Flexural strength of SCC improved at all the curing ages on use of iron slag as fine aggregate in partial replacement of river sand. At early curing age of 7 days, Flexural strength and compressive strength ratio increased with the increase in levels of sand replacement with iron slag in SCC. However, with the progress of curing age of 28 days, the effect of inclusion of iron slag in SCC on splitting tensile strength and compressive strength ratio is not so predominant

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